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ON THE NATURE OF VAN BIESBROECK'S STAR $+4^{\circ}4048B$

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ABSTRACT

Van Biesbroeck's star B D + $4^{\circ}4048$ (B) is the intrinsically faintest known star ($M_V = 18.6$). Kron has given a color temperature of about $2000^{\circ}K$ and color index (P-V) = 2.33 for this star. It is most probably a star of late M spectral type. Making use of these data and the theory of stars of very low mass, the following tentative conclusions are made about its structure and evolution. 1) It is not a main sequence star; i.e., hydrogen burning is not the source of energy production inside it. It is contracting slowly. 2) Its mass is less than 0.07 $M_{\odot}$. 3) It is a degenerate star that is slowly approaching the black dwarf stage.

Van Biesbroeck's star BD + $4^{\circ}4048$ B is the intrinsically faintest known star. Its visual absolute magnitude is $M_V = 18.6$ (Herbig, 1962) and Kron (1958) gives a color temperature of about $2000^{\circ}K$ for it. It is extremely red in color, with a color index (P-V) of 2.33. It is a single star and therefore, we do not know its mass. From its position in the H-R diagram, one would guess that this star is a main sequence star of low mass. This is, however, not correct because the lower end of the main sequence has a definite limit. Kumar (1963a) has shown that for population I stars ($X = 0.62$, $Y = 0.35$, $Z = 0.03$), the main sequence ends at $M \simeq 0.07\ M_{\odot}$. This limiting mass on the main sequence corresponds to an absolute magnitude $M_V \simeq 17$, which means that a population I star fainter than $M_V \simeq 17.0$ cannot be in the main sequence state (Kumar, 1963c). Therefore, van Biesbroeck's star cannot be a main sequence star. In other words, hydrogen burning is not the source of energy production in this star. We shall now show that it is most probably a degenerate dwarf of mass $M < 0.07\ M_{\odot}$. A degenerate dwarf is defined to be a star which is composed of degenerate matter and having <u>any</u> mass less than Chandrasekhar's limit. It may have any composition and its surface temperature may be as high as $30000^{\circ}K$ or as low as $0^{\circ}K$.

In order to show that van Biesbroeck's star is a degenerate dwarf of mass $M < 0.07$, we compute its present radius. Taking Kron's value of $2000^{\circ}K$ for the effective temperature and a bolometric correction of -4.5 (Johnson 1962), we obtain

$$\log R/R_{\odot} = \tfrac{1}{2} \log (L/L_{\odot}) - 2 \log (T_e/T_{\odot}) = -0.96$$

$$\text{or } R/R_{\odot} \simeq 0.1$$

Since a degenerate dwarf of mass greater than 0.07 (i.e., a white dwarf) cannot have such a large radius (Chandrasekhar 1938), its mass must be less than 0.07. It is possible that the radius computed above is in error by a factor of two or three because of the uncertainty in the effective temperature and the bolometric correction. However, it is unlikely that the radius of the star is in the range 0.05 - 0.03 $R_{\odot}$, because that would mean that it is a degenerate dwarf of mass 0.07 - 0.2. This possibility is ruled out because it implies that van Biesbroeck's star has reached its present state after going through the main sequence stage. Obviously, the Galaxy will have to be much older than 1.5×10^{10} years if our star is a degenerate dwarf of mass 0.07 - 0.2.

We propose, then, that van Biesbroeck's star is a contracting star of mass $M < 0.07$ and that it is slowly

approaching the black dwarf stage. As has been pointed out by Kumar, all population I stars of mass $M < 0.07$ become completely degenerate objects as a result of gravitational contraction and, in all likelihood, the star under study is one such object. Could the nuclear reactions involving the destruction of Deuterium and Lithium halt the contraction for a long time? No. As has been shown by the author (Kumar, 1963b), these reactions can increase the Helmholtz-Kelvin time scale for very low mass stars by not more than a factor of two and the total time scale for contraction down to the stage of maximum central temperature is equal to or less than one billion years.

It should be pointed out that this star is not a unique star. All stars of very low mass pass through a stage similar to the one van Biesbroeck's star has now and all of them eventually become black dwarfs or planetary objects. Two more stars which are undergoing this kind of evolution are the two components of the system L726-8. The masses of the two components are 0.044 and 0.035 (van de Kamp 1959) and most probably both of them are contracting stars composed of partially degenerate matter. The fact that van Biesbroeck's star is fainter and redder than L726-8B indicates that the former is probably an older star of mass $M \simeq 0.04$. But, on the other hand, it is also possible that van Biesbroeck's

star's mass is $\simeq$ 0.01 and it is not older than L726-8B. At the present time, we cannot distinguish between these two possibilities. In conclusion, we may say that all faint stars which are very red in color are most probably degenerate stars of very low mass.

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